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• N A T I O N A L •

PRECASTER

NATIONAL PRECAST CONCRETE ASSOCIATION AUSTRALIA

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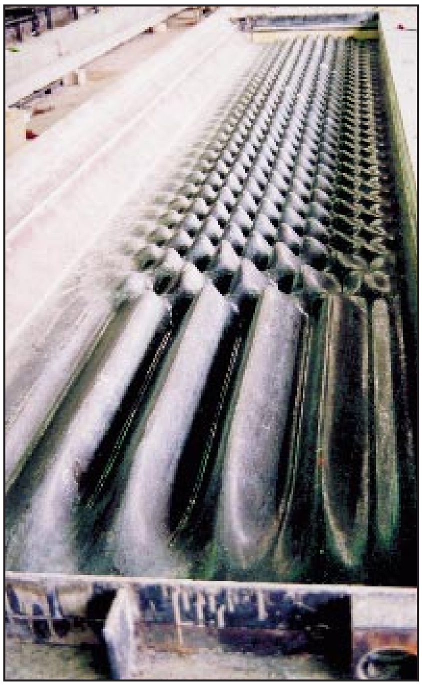
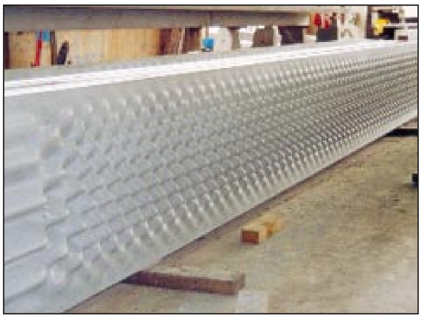
Erection of moulded facade panels.
Note asymmetrical design of wall elevations.

PRECAST Case Study – Canberra's National Museum

Computer patterned concrete mould being set up in precast factory (below) and finished facade panel, one day old and ready for delivery (right).





PROJECT BACKGROUND

One of the most innovative buildings in Australia is the Acton Peninsula Alliance project being constructed on the Acton Peninsula in Canberra. It consists of two new facilities – The National Museum of Australia and the Australian Institute of Aboriginal and Torres Strait Islander Studies.

Acton Peninsula Alliance is the design and construction team responsible for delivering the project and includes Bovis Lend Lease Pty Ltd as builders and Ashton Raggatt McDougall and Robert Peck von Hartel Trethowan as architects.

This new development on the Acton Peninsula will be a highly attractive addition to Canberra's landscape and cultural life and a long awaited national cultural institution. It will take its place alongside the Australian Parliament, the High Court of Australia, the National Library, the National Gallery of Australia, the National Film and Sound Archive, the Australian War Memorial and the Australian National Botanic Gardens as major cultural attractions with important national roles. The museum complex will open in 2001 as the flagship for Australia's Centenary of Federation celebrations.

PRECAST CONSTRUCTION

Precast concrete plays a major part in the National Museum – both structurally and architecturally. The buildings are very complex and the precast components were therefore challenging for the manufacturer, Rescrete Industries, to draw and to produce.

The project architect, Howard Raggart, commented on the construction technology philosophy as "something to dream about – surfaces, structures and services in one seamless file, emailed for manufacture to arrive in easy to assemble components. Complex surfaces are unfolded, transforming facade construction into a kind of giant dressmaking."

The innovative use of precast and the precast industry's response to the challenges make an interesting case study.

Facade The stunning facade comprises 260 wall panels with a profiled surface designed in three dimensional graphics by the architect. The 1200 mm wide panels were up to 13 m in height and varied in weight from 1 to over 10 tonnes. The geometry was complicated in some instances by the panels leaning outwards as well as tilting sideways. The facade profile was transferred to the moulds for precast production directly from the architect's CAD CAM generated files and shop drawings. The precast panels were cast face-down in concrete and steel moulds and left off-form for painting on site.

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Prestressed hollowcore panels are used to clad part of the Gallery of Aboriginal Australia section of the Museum. These panels were left smooth for painting on site. Hollowcore walls are a very economical medium for obtaining fast, high-quality cladding.

Flooring Precast flooring is being provided for four buildings and consists of hollowcore prestressed 200 mm and 250 mm deep planks, Transfloor™ and beamshells. Precast flooring gets critical construction activities off site and allows immediate access to the floor as a working platform.

Hollowcore floor panels installed to speed up construction.

SUMMARY

The key people involved with the design and construction of this landmark project are delighted with the role that precast has played.

The techniques used to draw and manufacture the facade panels on this project open up a whole new area of architectural expression in this country. Computer generated 3-D profiles and computer controlled cutting technology mean that we have the ability to translate architectural ideas into reality to a far greater extent than previously.

Bovis Lend Lease Project Manager, Goran Adzic, was enthusiastic about the advantages of precast concrete, saying "The use of five distinct precast products in the floors and walls of the Acton project demonstrates the ability of Australia's precast industry to design and deliver solutions to construction problems which are innovative, timely and cost effective. We shall be looking for opportunities to exploit precast solutions to construction problems in the future." ■

Acknowledgements

Bovis Lend Lease Pty Ltd, on behalf of Acton Peninsula Alliance – for appropriate background information.

Photocall Australia – for supply of photographic slides.

PRECAST Connections and Fixings

This is the first in a three-part technical advice series providing guidelines for the design of connections and fixings used to attach precast elements to each other and the main structure. The series features guidance on design and illustrates various types of connections and fixing, eg cladding panel, column units and corbels.

INTRODUCTION

Connections are defined as the system or assembly used to tie a precast member to the supporting structure or to an adjacent member while fixings are the hardware component of connections.

In the design of connections structural redundancy is generally eliminated to minimise forces. Therefore, it is critically important that load paths for forces through the structure, from elements through connections down to the footings and foundation are carefully reviewed. Where possible it is prudent to design a statically determinate system, which will accommodate long-term, incremental volume-change movement. Consideration of connection behaviour during both erection and the life of the structure are important.

Practical and economical connection design must consider the manufacture of the elements and construction techniques, as well as the performance of the connections for both serviceability and ultimate limit states. Design of the overwhelming majority of connections is a simple everyday affair but the principles summarised here are the basis of all connection design.

GENERAL DESIGN CRITERIA

Connections and fixings must meet the following criteria.

- Structural Adequacy
- Ductility
- Accommodation for Volume Change
- Durability
- Fire Resistance
- Production Simplicity
- Construction Simplicity.

Structural Adequacy A connection must resist the forces to which it will be subjected during its lifetime. Some of these forces are apparent, for example those caused by dead and live gravity loads, wind, earthquake, and soil or water pressure. Others are not so obvious and are frequently overlooked. These are the forces caused by restraint of volume changes in the elements (see below) and forces required to maintain stability. Instability can be caused by eccentric loading, as well as lateral loads from wind and earthquake. Measures taken to resist instability may aggravate the forces caused by volume changes, and vice versa.

The connection resistance can be categorised by the types of force to which it is subjected. These include:

- Compression
- Tension
- Flexure
- Shear
- Torsion.

Many connections will have a high degree of resistance to one type of force, but little or no resistance to another. For example, a connection may have a high shear capacity and little or no moment capacity. For a given type of connection it may be unnecessary, or even undesirable to provide a high capability to resist certain types of forces.

Simple bearing connections are effective and economical

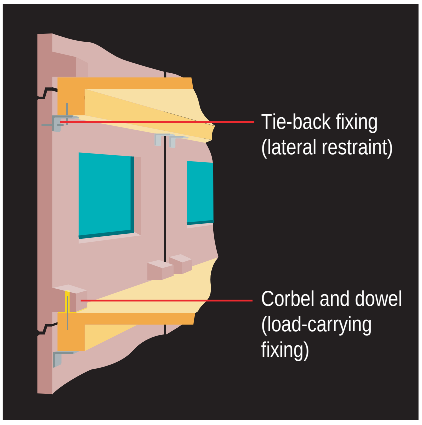
Ductility For the purpose of design of connections, 'ductility' is defined as the ability to accommodate large deformations without failure. In structural materials, ductility is measured by the amount of deformation that occurs between first yield and ultimate failure.

Ductility in building frames is usually associated with moment resistance (rotational ductility) and in the case of precast structures may have a major impact on connection design. Flexural or direct tension is normally resisted by steel components, either reinforcing bars or structural steel sections. Connections are proportioned so that first yield occurs in this steel component, and final failure may be from rupture of the steel, crushing of the concrete, or a failure of the connection of the steel to the concrete.

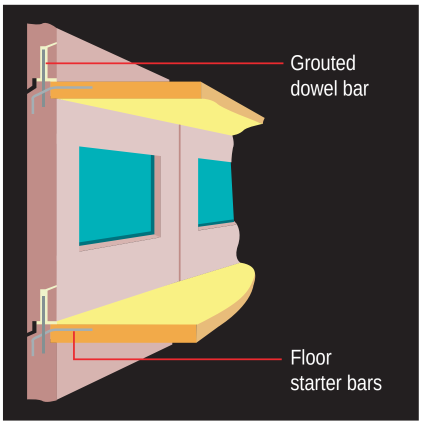
Accommodation for Volume Change The combined effects of shrinkage, creep and temperature differences can cause severe stresses on precast concrete elements and their supports if the end connections restrain movement. A connection should either be able to accommodate these strains or be strong enough to withstand the induced forces, or a mixture of the two. (These stresses must be considered in the design, but it is usually far better if the connection will allow some movement to take place. This can be achieved by slotted holes or sliding bearings). Build-up of force due to these effects takes time and it can take many years before the full effects are felt.

Most of the severe problems that have been caused by restraint of volume change movements have appeared when relatively long elements such as floor deck units have been welded to the supports at both ends, eg the collapse of roof elements of a school building in Antioch after 20 years. When such elements are welded only at the top, experience has shown that volume changes are adequately accommodated. On relatively short, heavily loaded elements such as beams, an unyielding top connection may attract negative moment which is difficult to design for. Prestressed elements rarely exhibit cracking at locations further from the ends than the transfer length of the strand.

Durability A connection should be durable for the environment in which it is placed. (When exposed to weather, or used in a corrosive atmosphere, steel elements should be adequately covered by concrete, be hot-dipped galvanised or be of stainless steel. Reinforced elements should have adequate cover of quality concrete.) In marine environments stainless steel may be required for particular fixings. Dissimilar metals should not be directly coupled.



Cladding panels – the most common fixing method for multi-storey buildings is elegant and economical



The most efficient way to utilise precast cladding is to make it loadbearing, the connection details are straightforward

Fire Resistance Many precast concrete connections are not vulnerable to the effects of fire and require no special treatment. For example, the bearing between slabs or stemmed units and beams do not generally require special fire protection. If the slabs or tee beams rest on elastomeric pads or other combustible materials, protection of the pads is not generally needed because deterioration of the pads will not cause collapse. After the fire the pads can be replaced.

Other connections should be protected from the effects of fire to the same degree as that required for the members connected. The requirements in the BCA will need to be satisfied. For example, an exposed steel bracket supporting a beam may be weakened enough by a fire to cause failure and dislodge the beam from the structure. Such a bracket should be protected.

Connections which require a fire resistance rating will usually have exposed steel elements encased in concrete. Other methods of fire protection include enclosing with gypsum wallboard, coating with intumescent mastic, or spraying with fire protection material.

There is evidence that exposed steel hardware used in connections is less susceptible to fire-related strength reduction than other exposed steel elements. This is because the concrete elements provide a 'heat sink', which draws off the heat and reduces the temperature of the steel.

Production Simplicity Maximum economy of precast concrete construction is achieved when connection details are kept as simple as possible, consistent with adequate performance and ease of erection. Furthermore, complex connections are more difficult to control and will often result in poor fit in the field. This can contribute to slow erection and less satisfactory performance.

The following is a checklist of items to consider in order to improve production procedures:

- Connections often require congested reinforcement, embedded plates, inserts, blockouts, etc. Frequently the number of items concentrated into an area means that there is virtually no room for the concrete. In some cases, it may be economical to increase the element size just to avoid congestion. Also, details such as dapped or recessed ends should be avoided unless necessary. They require special reinforcement in a constricted area and are always congested.
- Reinforcing bars and prestressing strands or ducts, which usually appear as lines on drawings, have real cross-sectional dimensions. In the case of bars these are larger than the nominal bar diameter because of the deformations. This must be considered in the design phase.
- Bends in reinforcing bars require minimum radii, which can cause fit problems or lead to loss of cover. Generally, and especially if congestion is suspected, details of the area in question should be drawn to a scale of at least 1:5 to ensure everything can be fitted together and concrete placed and compacted. Remember elements are usually cast in forms with concrete deposited from the top and sufficient space for vibrators should be provided.
- Similar details should be identical even if it may result in a slight over-design. This will result in fewer form set-ups and improve scheduling. Wherever possible, hardware items such as inserts, studs, steel shapes, etc, should be standard items that are readily available.
- Fixings that have projections, which require cutting through the forms, are difficult and costly to place. Where possible, these fixings should be placed only in the top of the element as cast.

Even this inhibits finishing of the top surface. This is important on deck elements, double tees, hollow-core slabs as well as wall panels. Cast in ferrules are preferred to projecting bolts.

- Items that are embedded in the element, such as inserts, plates, reglets, etc, require time and care to locate precisely and attach securely. Such items should be kept to a minimum.
- A precasting operation is most efficient when the product can be taken directly to the storage area immediately after it is stripped from the form. Any operations which are required after stripping and before placement at the job site, such as special cleaning or finishing, or welding on projecting hardware, should be avoided whenever possible.
- Tighter dimensional tolerances than industry standards are difficult to achieve. Connections which require close-fitting parts without provision for adjustment should be avoided.
- Inserts used for lifting should not be easily confused with inserts of a lesser capacity used as tiebacks or other purposes.
- Precast concrete manufacturers should be allowed to use alternative details, methods or materials, provided the design requirements are met. These will often result in the most economical and best-performing connections.

Starter bars for a loadbearing column connection

Construction Simplicity Much of the advantage of precast, prestressed concrete construction is due to the possibility of rapid erection of the structure. To fully realize this benefit, and to keep costs within reasonable limits, field connections should be kept as simple as possible. The following is a list of items that should be considered during the selection, design and detailing of connections to facilitate speedy and safe erection:

- Hoisting the precast elements is usually the most expensive and time-critical process of erection. Connections should be designed so that the element can be lifted, set, and unhooked in the shortest possible time. Before the crane can be unhooked, the precast element must be in its final position, stable and secure. Precast elements such as double tees and hollow-core slabs are inherently stable and require no additional connections before releasing the crane. Others, such as columns, deep beams, wall panels and single tees usually require some supplementary shoring, guying, or fastening before the crane can be unhooked. Pre-planning for the fewest and quickest possible operations that must be performed before releasing the crane will greatly facilitate erection.
  In some cases, it may be necessary to provide temporary fasteners or levelling devices, with the permanent connection made after the crane is released. These temporary devices must be given careful attention to ensure that they will hold the element in its proper position during the placement of all elements that are erected before the final connection is made.
- A certain amount of field adjustment at the connections is always necessary. Normal fabrication tolerances will preclude the possibility of a perfect fit in the field. This is true not only when the precast elements adjoin each other, but, even more so, when the precast elements must interface with insitu construction.
  Adjustment in the field is accomplished through the use of slotted or oversize holes for bolts and dowels, field welding, shims and grout.
- Connections should be planned so that they are accessible either from the completed structure or a stable deck or platform. The type of equipment necessary to perform such operations as welding, post-tensioning, or pressure grouting should be considered. Operations which require working under a deck in an overhead position should be avoided, especially for welding. Room to place wrenches on nuts and swing them in a large arc should be provided for bolts. Dry-packing column or wall panel bases in a narrow excavation is difficult.
- Materials such as grout, dry-pack, cast-in-place concrete, and epoxies need special provisions if they are to be placed in cold weather. Welding will require special precautions when the ambient temperature is low. Connections should be designed so that delays due to inclement weather are avoided.
- Reinforcing bars, steel plates, dowels, and bolts that project from the precast element can be damaged if care is not taken during handling and require repair. Anchor bolts that project from cast-in-place footings should be at least 24 mm in diameter so that there is less chance of them being bent. Threads on projecting bolts should be protected from damage and rust.

Loadbearing connections in architectural facades should be simple and not obtrusive

These production and construction considerations can be summarised as:

- Standardise products, details and hardware
- Avoid reinforcement and hardware congestion
- Avoid penetration of forms
- Reduce post-stripping work
- Be aware of material sizes and limitations
- Consider clearances and tolerances and avoid non-standard production and erection tolerances
- Plan for the shortest possible crane hook-up time
- Provide for field adjustment
- Use connections that are not susceptible to damage in handling
- Ensure the panel has stability when the crane is unhooked and allow for late adjustment for correct alignment
- Locate connections so that they may be installed on a single floor and don't require work parties on two floors at once. ■

ISSUE 24 of National Precaster *will cover in the second part of this series, advice on cladding panel connections, loadbearing connections and bearing pads. Moreover, a more detailed treatise on the subject will be covered in the* **PRECAST CONCRETE HANDBOOK** *to be published by the NPCAA and CIA later this year.*

Precast panels on Sydney Hotel/Casino complex using 0.75% yellow oxide

OXIDE Colouring Pigments in Precast and GRC

1 INTRODUCTION

Oxide pigments are commonly used to colour architectural precast concrete and glass reinforced concrete (GRC). Any pigments incorporated into concrete for exterior use must be colourfast. Also they must not harm the durability of the concrete. All references to precast concrete below also apply to GRC.

2 APPLICATION

General Colouring pigments used in precast concrete are predominantly metal oxides. These do not change colour or fade as no chemical change can occur with them at normal temperatures.

Dosage Rates The dosage rates for precast concrete are typically 0.25% to 1% by weight of cement. Some off-form and other precast concrete finishes may require as much as 8%. The rates best suited to any project will be provided by the precaster and confirmed by architectural samples.

3 CHARACTERISTICS OF METAL OXIDE PIGMENTS

General Fine solid oxide pigment particles rely for their effectiveness on being adequately dispersed throughout the mixed concrete. They do not dissolve and stain the concrete as a dye colourant does.

Type and Availability Pigment colours range from deep solid to pale pastel. The major non-blended standard pigments are green, black, red, brown, yellow, blue and white. These can be obtained in commercially blended form to produce many intermediate colours.

Characteristics Pigments for use in precast concrete should have the following characteristics:

- be chemically inert and particularly alkaline resistant
- be insoluble
- be chemically inorganic to prevent fading by photochemical degradation.

Mineral (metal) pigments such as oxides of iron (reds, blacks and yellows), chromium (greens), titanium (white) etc, fulfil the above requirements.

4 PIGMENTED CONCRETE AND IN-SERVICE CONDITIONS

Colour Stability The colour stability of precast concrete coloured with mineral oxide pigments can be affected by the degree of durability and weathering of the concrete rather than by any characteristic of the pigments.

The primary cause of colour changes of the concrete are efflorescence, atmospheric etching and staining and any accumulated dirt and grime. These causes can be controlled by producing precast units of high performance quality concrete that have been well detailed.

Just like all material surfaces left in an open-air environment, precast concrete must be occasionally cleaned to remove pollution and restore colour.

Samples The same rules should apply to pigmented precast concrete sample evaluation as they apply to the assessment of other architectural precast. Small samples give a guide but existing buildings with similar design should be viewed and evaluated if possible. The first panels of a production run, or prototypes if they are specified, must always be inspected by the client or agent to ensure that the design requirements are being achieved.

An excellent result is usually achieved through the use of a competent precaster experienced in the manufacture of architectural finishes.

5 STANDARDS

There is no Australian Standard for the use of mineral oxide pigments in precast concrete. ■

Patterned precast retaining wall units on Melbourne Freeway project using 7.6% deep marigold oxide

The NPCAA publication ***PRECAST CONCRETE HANDBOOK*** will deal with this matter in more detail. In the meantime, should you require further information, please contact the NPCAA on [02] 9890 8853 so a Data Sheet can be mailed.

Olympic Superdome constructed using post-tensioned band beam system which was used on five levels with a total of 30 000 m^2 of standard beams.

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ULTRAFLOOR PTY LTD, a Corporate Member of the NPCAA since 1997, introduced its unique composite prestressed flooring system to the Australian building market in 1991. Their flooring system utilises prestressed beams working compositely with the concrete topping to achieve the most efficient use of the materials. The system was developed with the cooperation of Professor Rob Wheen at Sydney University.

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The Ultrafloor system is used extensively in all segments of the flooring market – housing, medium density apartments, industrial and high-rise construction by reason of the following benefits:

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- Structurally efficient – long spans, high load capacity, reduced weight.
- Inherent flexibility to accommodate services and to incorporate many structural details.
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Ultrafloor has manufacturing facilities in NSW, Victoria and WA (under license) and has sales offices in Brisbane, Rutherford, Sydney, Melbourne and Perth. ■

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NEW MEMBER

The President, Directors and Members of NPCAA welcome the forthcoming support of this new member in further consolidating the status of the precast concrete industry.

CORPORATE MEMBER

Icon Industries Pty Ltd recently acquired the well-known NSW company Ci&D Pty Ltd and will continue to specialise in a wide range of precast products including stormwater pits, highway products and trade waste arrestors.

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